ELECTRICAL ENGINEERING RESEARCH LABORATORY
THE UNIVERSITY OF TEXAS
Austin, Texas

FINAL REPORT

Contract NASr-87

covering

DESIGN, FABRICATION AND INSTALLATION OF A 16-FOOT PARABOLIC REFLECTOR ANTENNA

to

National Aeronautics and Space Administration
Washington, D. C.

30 June 1963

21053

ABSTRACT

Contract NASr-87 between the National Aeronautics and Space Administration and The University of Texas was entered into on December 11, 1961 when signed by T. L. K. Smull for NASA. This contract provided for the design, fabrication and installation of a 16-foot parabolic reflector antenna at the Balcones Research Center, The University of Texas. A period of 18 months was provided for the completion of the objectives of this contract.

A subcontract to Philco Corporation, Palo Alto, California was placed for the building of the reflector and associated equipment and the installation in Austin, Texas. The antenna was tested at 70 kMc/s by personnel of The University of Texas and was found to be in general agreement with the specifications which were set out in the contract. Acceptance of the antennas was made by National Aeronautics Administration by letter of Mr. T. L. K. Smull on May 23, 1963. Research with this antenna is in progress under National Aeronautics and Space Administration Grant NsG-432.

I. INTRODUCTION

The development of techniques in the millimeter radio frequency range has provided the possibility of investigating the radiation from the moon and planets by passive means at frequencies higher than previously used. To effectively carry forward the program of the examination of the moon and the planets at these higher frequencies, an antenna was required with a larger reflector than was currently available at these short millimeter wavelengths. It appeared desirable to try to extend the state of the art in the construction of reflectors to such an extent that measurements could be made to wavelengths as short as 2 millimeters. Such measurements are intended to provide substantial backup information for the NASA space program by giving earth reference data on lunar and planetary temperatures during the exploration of the moon or of the planets. Emission data on the temperature variation across the moon will be of assistance in evaluating landing sites and in obtaining information concerning the surface characteristics of the moon.

In order to obtain these objectives, it was proposed to National Aeronautics and Space Administration by the Electrical Engineering Research Laboratory of The University of Texas that a radio telescope capable of measurements to wavelengths as low as 2 millimeters be constructed for the observations described above.

II. SELECTION OF SUBCONTRACTOR

In cooperation with representatives of National Aeronautics and Space Administration, The University of Texas developed specifications which would be required for the correct operation of the proposed millimeter antenna. The techniques of achieving the desired specifications were kept to a minimum in order to allow companies who wished to propose systems to accomplish the objective of the antenna design with as much freedom as possible in the design of the antenna system.

The requirements for the antenna were submitted to eleven companies who expressed interest in the building of the millimeter antenna system. These eleven companies are as follows:

Advanced Structures, La Mesa, California
American Machine and Foundry, Greenwich, Connecticut
Antenna Systems, Bingham, Massachusetts
Blaw-Knox Company, Pittsburg, Pennsylvania
Boeing Aircraft Company, Seattle, Washington
Chance-Vought Aircraft Company, Arlington, Texas
D. S. Kennedy, Cohassett, Massachusetts
ITE Circuit Breaker Company, Philadelphia, Pennsylvania
Philco Corporation, Palo Alto, California
Rohr Aircraft Company, San Diego, California
Temco Aircraft Company, Garland, Texas

The responses to the requests for proposals were quite varied in character and certain inadequacies appeared in all of them. Chance-Vought and Temco did not submit bids and several others offered only conventional equipment which obviously would not be satisfactory for extending the state of the art in the use at the shorter millimeter wavelengths. The proposals which were received were reviewed by a NASA advisory panel composed of men from various university and government agencies. In the opinion of The University of Texas representatives and with the approval of this committee and the representatives of NASA, three of the companies were judged to have submitted proposals which were in general agreement with the specifications set out in the bids for proposals. These three companies were Advanced Structures, D. S. Kennedy, and Philco Corporation. Visits were made to these three companies by personnel of NASA and The University of Texas to clarify uncertainties in techniques proposed, and bids were resubmitted by them on a comparable basis which eliminated shortcomings in their original proposals. [redacted]

[redacted]

On the basis of the quality of the proposals, the apparent capabilities of the companies and the amounts of the bids, the Electrical Engineering Research Laboratory recommended to NASA that Philco be awarded the subcontract for the antenna system. This recommendation was approved by NASA and the subcontract was let to Philco Corporation in January 1962. The details of the antenna system were described in the proposal of the Philco Corporation which was quite lengthy and, since copies of it are available at National Aeronautics and Space Administration, it will not be incorporated in this report.

III. SUMMARY DESCRIPTION OF THE ANTENNA

The University of Texas radio telescope was designed, built and installed by Philco WDL, and consists of a 16-foot diameter parabolic reflector, a tetrapod that holds the feed at the focal point of the reflector, an equatorial mount, polar and declination drive and control system, a concrete foundation, and an observatory dome.

Reflector

The 16-foot reflector consists of a honeycomb parabolic surface attached to a truss backup structure. Both the honeycomb panel facings and the truss structure are made of invar, a steel alloy which has an extremely low coefficient of thermal expansion. This property prevents temperature changes from distorting the accuracy of the reflective surface.

The reflective surface was formed in several steps. First, honeycomb panels were accurately molded. When installed on the backup structure, the panels were riveted and bonded into place to form a permanent one-piece structure. Next, a thin plastic coating was applied to the surface and smoothed to a very precise contour by the Philco Microsweep process. Finally, the metallic conductive coating was built up by brush-plating to a thickness of approximately 45 millionths of an inch. The finished reflective surface has a measured accuracy to within 0.003 inch rms and provides an unbroken, continuous surface.

The reflector was built at Palo Alto and shipped to the site in a specially designed shock-resistant container. This procedure insured that the accuracy built in during manufacture would not be disturbed.

Feed Support

The four-legged feed support is also made of special invar tubing to eliminate thermal distortion, and is sufficiently stiff that the fifty-pound feed cannot shift its position more than three-thousandths of an inch as the telescope is moved about.

Equatorial Mount

The reflector is gimbal-mounted to permit motion about either of two axes. The polar axis is parallel to the true axis of the earth's rotation, that is, it points at the North Star. Rotation of the telescope about the polar axis moves the reflector in an east or west direction. The declination axis is perpendicular to the polar axis, and motion about the declination axis moves the reflector in a north or south direction, that is, toward or away from the North Star. The reflector can "look" at any part of the sky from Polaris to the southern horizon, and horizon to horizon in the east or west direction.

The gimbal is a welded steel structure designed for stiffness. The gimbal contains all drive gear trains as well as the declination axis bearings. The two axes of the telescope intersect and are perpendicular to one another within one second of arc. The reflector support arms straddle the gimbal and rotate about the declination axis. The counterweights used to balance the reflector are attached to the ends of the reflector support arms. The intersecting axis design permits a single set of counterweights to balance the entire mass in any position.

The gimbal is supported by the polar axis bearings mounted on top of the north and south towers. The polar bearings are adjusted to align the polar axis parallel to the earth's axis within one second of arc.

Drive and Control System

East and West motion is obtained from the polar drive, in which the drive pinion, mounted on the gimbal, "walks" around the sector gear attached to the south tower. North and south motion comes from the declination drive pinion, also gimbal-mounted, which drives the declination sector gear attached to the reflector support. The sector gears are 36 inches in pitch diameter and have a face width of 1 1/4 inches. These gears are 8 diametral pitch (approximately 1/4 inch tooth thickness). The polar axis drive pinions are integral with the motors and the reduction ratio is 16 : 1. The declination axis drive goes through a gear reduction before the final drive stage, and its overall reduction ratio is 820:1.

Both axes are driven by dual drive systems (two direct current torque motors on each axis). The two drives are biased against each other to eliminate backlash. The polar axis motors are controlled by silicon-controlled rectifier power amplifiers. The axis position is sensed by a 27-pole resolver, which, together with a linear tachometer, provides the feed back control system.

The polar axis rate is controllable by 0.001 degree increments from one-thousandth of a degree per second to four degrees per minute. The declination control is a position control, directing the motors through transistor power amplifiers. Each turn of a handwheel at the console causes the declination axis to rotate 0.45 degree.

Both axes can be slewed at one degree per second. Both axes are equipped with Datex angle encoders which show the telescope position to an accuracy of ± 0.001 degree.

Foundation

The telescope is mounted on a concrete foundation consisting of three elements: pedestal, slab, and dome ring. These are separate elements and relative movement between them is permitted by felt seaprators. This prevents wind loads on the dome from introducing unwanted loads into the pedestal. The 26,000 pound telescope is mounted on the concrete pedestal which weighs approximately 42 tons.

Observatory Dome

The telescope is protected from excessive wind loads by a 35-foot diameter observatory dome with shutters opening to an aperture width of 19 1/4 feet. The dome rotates on rubber-tired wheels to align the shutter opening with the telescope pointing direction.

Performance

In measurements made at 70 Gc (70 billion cycles per second) the reflector measured gain was 67.8 decibels, the first sidelobe was -19 db, other sidelobes -28 db, and the beamwidth was 0.058 degree. The reflector accuracy is sufficient to permit operation at frequencies up to 300 gc.

IV. PROPOSED USES OF THE ANTENNA IN RESEARCH

The 16-foot diameter antenna system, equatorially mounted for the prime purpose of making astronomical observations, is located at The University of Texas' Electrical Engineering Research Laboratory, longitude 30°23'17" north, latitude 97°43'37" west. The antenna is singularly unique in its capability of efficiently observing millimeter wavelength radiation that is inaccessible to existing radio telescopes. The 16-foot diameter parabolic reflector, with a surface area of 201 square feet, concentrates approximately ten million times as much energy at the prime focus of the parabola as is available in the absence of the parabola. Normal operating wavelengths of the telescope are between 30 mm and 2 mm.

Over the 30 to 2 mm wavelength interval - and shorter wavelengths- the gases of the earth's atmosphere emit and absorb significant quantities of energy. The absorption reduces the radiation from outside the atmosphere available to the telescope and the emission partially blinds the telescope. The less dense and thick the atmosphere look-through, the more capable the telescope is of seeing faint extraterrestrial radiation.

The physics of space and the bodies of the solar system are of particular interest to NASA. By observing the radiation from the earth's moon and the planets over a wide interval of wavelengths, the physical features of these bodies can be hypothesized. Since the solar bodies, with the exception of the moon, lie near the ecliptic plane, a minimum of encumbrance by the earth's atmosphere to the "seeing" of the telescope is obtained for telescope locations at low latitudes.

The self-emission of the earth's atmosphere, primarily from water vapor and oxygen, over the wavelength interval of 30 to 2 mm is characterized by varying emission intensities that are a function of the particular wavelengths being observed. These emission intensity signatures are not only associated with gases but also with land and water surfaces. In order to identify the constituents, densities, and temperatures of the atmospheres and surfaces of the planets, these signatures are some of the features that will be looked for when observing the solar bodies. Only the characteristics of the total atmosphere and/or surface can be identified for objects, such as the planets, that subtend small angles. Because of the larger angle subtended by the moon, the characteristics of areas approximately one-tenth the diameter of the moon can be resolved with the mid-range operating wavelength antenna beam of 1 milliradian. Based on the emission levels from lunar surface area reacting to solar heating, the probable composition of the upper stratum of the moon can be hypothesized.

The knowledge to be gained from the earth-based observations of the solar bodies is expected to aid NASA in designing and packaging the experiments that will in greater detail explore the bodies of the solar system.

Beyond the solar system, many light years distant, other systems of the galaxy and other galaxies beyond our own are to be viewed with the new radio telescope. The relative nature of the appearance of galactic and extragalactic radiation at the millimeter operating wavelength of the telescope will be observed.

The telescope has a capability of seeing approximately ten times as well, or three times as far, at the short millimeter wavelengths as existing radio telescopes. Opening of the millimeter portion of the electromagnetic spectrum to clearer seeing is a step in bridging the gap between optical and radio astronomy. The University of Texas' radio telescope will add a new dimension to the existing knowledge of the emission characteristics of the solar system, the galaxy and other galaxies. This knowledge will complement that gained at centimeter and meter wavelengths with other radio telescopes.

VI. NATIONAL SCIENCE FOUNDATION SUPPORT

National Science Foundation Grant G-13420 [redacted] was received by The University of Texas on 14 June 1960 for studies on the design and development of a small millimeter antenna system. At about the same time, the initial studies for the 16-foot reflector antenna were started. With the approval of National Science Foundation, the funds for NSF Grant G-13420 were diverted to the costs involved in the design studies for the 16-foot reflector antenna. This grant provided salaries, travel, equipment, and miscellaneous expenses required for the support of the 16-foot antenna development. This supporting grant is gratefully acknowledged.